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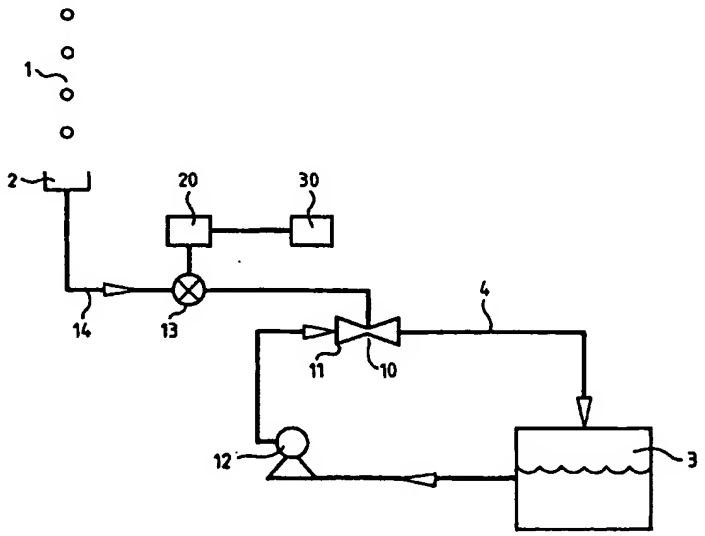

(57) Abstract

The invention relates to a method for operating a continuous ink jet printer so as to reduce the loss of volatile solvent or carrier from ink recycled from a gutter (2) to a reservoir (3), the printer having an ink flow system in which ink flows from a reservoir (3) to a print head from which it is ejected to form a series of discrete droplets (1) directed at a substrate upon which an image is to be formed by applying droplets to the surface of the substrate and in which droplets which are not to be applied to the substrate are collected in the gutter (2) and are recycled to the reservoir (3) of the ink flow system for re–use, the method comprising removing ink from the gutter by suction which is varied, pulsed or interrupted. The invention also relates to a continuous ink jet printer for use in the method of the invention in which means are provided for varying, interrupting or pulsing the application of suction to the gutter.

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INK JET PRINTER AND METHOD OF OPERATION

The present invention relates to an apparatus and to a method for operating that apparatus, notably to an apparatus and method for reducing the loss of solvent from the stream of ink being re-cycled in a continuous ink jet printer.

BACKGROUND TO THE INVENTION:

During the operation of what are known as continuous ink jet printers, a jet of ink is formed at a narrow bore outlet to an ink chamber. This jet is broken up into a stream of discrete, substantially uniformly sized and spaced apart droplets by applying pressure or vibration pulses to the jet. Such pulses are typically achieved by means of a piezoelectric transducer applying high frequency vibrations directly to the ink in the ink chamber or via a wall of the ink chamber. In one version of such a printer, the wall is formed from or has applied thereto a piezoelectric crystal which flexes when a voltage is applied to the crystal so that the wall of the ink chamber flexes and causes the internal volume of the ink chamber to reduce and thus eject a droplet of ink through the outlet to the chamber at each application of a driving voltage to the piezoelectric crystal.

The pressure within the ink chamber and/or the impulse force applied by the piezoelectric driver crystal causes the droplets formed by the break up of the jet of ink or the ejected droplet to fly towards a specific locus on a substrate to be printed and thus apply a printing droplet to that substrate.

A charging voltage is applied to the ink so that the droplets are either all charged to a uniform level or are individually charged to a predetermined but varying level. The charged droplets pass through a deflection field in which the inter action of the deflection field on the charged droplet causes the droplet to deflect to a predetermined amount from its straight line flight path from outlet of the ink chamber to the locus on the substrate. The direction and extent of deflection depends upon the charge carried by the droplet and the strength of the deflection field applied to that droplet. Usually, the droplets are all uniformly charged and its is the deflection field which is varied in synchronisation with the formation of each droplet so as to achieve the desired extent of deflection of each individual droplet. By varying the strength of the deflection field, each droplet can be applied to the substrate at a specified position on the substrate to build up a desired image. Alternatively, the droplets can carry a variable charge and the deflection field can be uniform, to achieve the same result.

For convenience, the term continuous ink jet printer will be used hereinafter to denote all such forms of printer in which a stream of charged droplets is passed through a deflection field so as to cause a predetermined extent of deflection of each individual droplet about the straight line un-deflected flight path of a droplet from the outlet from the ink chamber to the substrate.

Typically, it will not be desired to apply every droplet issuing from the print head of a continuous ink jet printer to the substrate. A gutter or catcher is therefore provided in the straight line flight path of droplets which have not been deflected away from this path so that those droplets are intercepted and are not allowed to reach the surface of the substrate, thus forming unprinted droplets. For convenience the term gutter will be used hereinafter to denote the mechanism by which the unprinted droplets are captured for recycle.

The droplets to form the printed image are those which are deflected to varying extents away from the straight line path and are thus not caught in the gutter. The droplets caught in the gutter can be discharged to waste. However, it is usually desired to recover these droplets and to recycle them for re-use. This is typically done by applying suction to the gutter to draw the droplets from the gutter into the ink flow path of the print head and thus return the droplets to the ink reservoir which feeds the ink chamber of the print head.

However, recycling of the droplets from the gutter raises other problems. For example, the ink will typically be a solution or suspension of dyestuffs and/or pigments in a volatile solvent carrier medium, notably methyl ethyl ketone, methanol, ethanol, isopropanol, acetone, ethyl acetate and mixtures thereof. Such volatile solvents escape from the ink droplets during their flight between the print head and the gutter. Air is also sucked into the gutter by the suction applied by the venturi or other pump typically used to draw the droplets from the gutter

into the ink flow system of the print head. The material recycled to the reservoir will thus be a mixture of air, solvent vapour and ink.

The solvent vapour laden air stream associated with the recycled ink droplets can be discharged to waste and only the liquid ink component of the recycled material returned to the ink reservoir. However, this not only represents a loss of the solvent values in the vapours discharged, but also discharge of an air stream rich in solvent vapours into the environment represents a fire and health hazard and is often forbidden by legislation. It is therefore typical for the recycled material to be cooled to condense out as much of the solvent vapour values from the air stream and to discharge the cooled material to the reservoir where the liquid ink and solvent mix with the main body of ink in the reservoir. However, it is still necessary to discharge the air component of the recycled material from the reservoir and this will inevitably contain some entrained solvent droplets and/or solvent vapours and must be treated to reduce these to a minimum before the air stream can be discharged into the environment.

Despite these problems, operators still wish to recycle ink droplets from the gutter and have concentrated on developing techniques for reducing the amount of solvent fluid or vapour lost in the air stream discharged from the reservoir to the environment.

Surprisingly, we have found that if the suction applied to the gutter to remove un-printed ink droplets therefrom is

not applied as a steady, continuous suction as hitherto, but is applied as an intermittent or pulsed suction, the amount of solvent vapour in the air stream to be discharged from the reservoir of the printer is reduced. We believe that this may be due at least in part to the reduction in the amount of air which is sucked into the ink flow system from the gutter, thus reducing the amount of solvent vapour which is stripped out of the liquid ink by the air stream. The reduction in the amount of air drawn into the ink flow system of the print head we believe also reduces problems associated with aeration of the ink in the reservoir which occurs with conventional un-printed droplet recycle systems.

SUMMARY OF THE INVENTION:

Accordingly, the present invention provides a method for operating a continuous ink jet printer so as to reduce the loss of volatile solvent or carrier from ink recycled from a gutter to a reservoir, the printer having an ink flow system in which ink flows from a reservoir to a print head from which it is ejected to form a series of discrete droplets directed at a substrate upon which an image is to be formed by applying droplets to the surface of the substrate and in which droplets which are not to be applied to the substrate are collected in the gutter and are recycled to the reservoir of the ink flow system for re-use, the method comprising removing ink from the gutter by suction which is varied, pulsed or interrupted.

From another aspect, the present invention provides a continuous ink jet printer having an ink flow system in

which ink is adapted to flow from a reservoir to a print head from which it is ejected to form a series of discrete droplets directed at a substrate upon which an image is to be formed by applying droplets to the surface of the substrate and in which droplets which are not to be applied to the substrate are to be collected in a gutter and recycled by means of suction via a duct to the ink flow system for re-use, characterised in that means are provided for varying, interrupting or pulsing the application of suction to the gutter.

Preferably, the suction is provided by a suction pump which is to operate continuously during operation of the ink jet printer and a valve is provided in the duct providing the fluid flow connection for the un-printed droplets between the gutter and the suction pump. Many continuous ink jet printers incorporate a venturi pump to draw un-printed droplets from the gutter into the ink flow system and have a valve located in the suction duct between the venturi pump and the gutter. The function of this valve is to provide a seal to this duct so that the remainder of the ink system can be pressurised during purging of the ink flow system, for example to eject ink or cleansing solvent between ink changes or to remove old or aerated ink during the start up of the printer after a rest period. The valve is thus in the fully closed position when the printer is not operating to print images on a substrate and is held in the fully open position during printing. It is not held in the closed or partially closed position during printing, since this would defeat the objective of the duct, namely to provide an open flow path by which un-printed droplets can flow

from the gutter to the ink flow system. However, in one aspect of the invention, this valve is provided with means by which it can be held intermittently in both the fully or partially open or closed positions during printing to achieve the variation in the suction applied to the gutter as required for the present invention.

The use of a valve is preferred since such valves are already present in most ink jet printer gutter lines - avoiding the need for additional components such as pumps and their control equipment. Moreover, their effect can readily be varied by altering the duty cycle and/or frequency of operation, which can be done by simple software.

Control means are provided for intermittently opening and closing the valve and thus interrupt the application of suction to the gutter during operation of the print head to apply droplets to the substrate to be printed. Alternatively, means can be provided for interrupting the operation of the suction pump, which will have the same effect. However, this may require replacement of the simple and effective venturi pump often used to apply the suction to the gutter with an electric pump and to provide additional control circuitry to control and interrupt the operation of the pump. The use of the venturi pump and control of the opening and closing of the existing valve in the duct between the venturi pump and the gutter provides a simple and effective means for implementing the present invention using existing components already present in a continuous ink jet printer and minimises the additional components required.

Accordingly, for convenience, the present invention will be described hereinafter in terms of a conventional continuous ink jet printer having a venturi pump connected by a valved duct to the gutter for recycling un-printed droplets from the gutter to the ink flow system of the printer.

The valve is simple to operate and the effect of shutting off the valve, and hence the suction on the gutter, can be varied simply by extending or shortening the open versus the closed times (the duty cycle) and/or the frequency of the cycle.

The valve can be of any suitable type, for example a rotary, solenoid, gate, butterfly, flap valve or the like. Thus, one form of the valve can be a rotary valve comprising a cylindrical or tapered plug member rotatably mounted in sealing engagement in a corresponding socket or recess in the body of the valve. The plug and socket are orientated transversely to the longitudinal axis of the duct in which the valve is mounted. The plug has one or more radial ports therethrough which are brought into and out of alignment with corresponding ports in the wall of the valve body defining the socket within which the plug is rotatably mounted. The plug can be rotated by means of a stepper motor through increments, for example of 90°, to open and close the flow path of fluid through the valve. In place of a rotatable plug, the obturator of the valve may be a transverse flap carried by a shaft located diametrically transversely across the duct which co-operates with semi-circumferential ridges on the inner

wall of the duct to provide a seal when the plane of the flap extends radially across the duct, but which provides a fluid flow path when the plane of the flap is orientated axially with respect to the longitudinal axis of the duct. Alternatively, the valve may be one in which the obturator moves linearly, for example as when a transverse gate or plug is moved into and out of the bore of the duct within a valve body by a solenoid or other mechanism.

For simplicity, the invention will be described hereinafter in terms of a conventional linearly acting plug which is moved within a valve body by means of an electrically operated solenoid. Such valves are commercially available and may have one or more passages therethrough to register with one or more ports in the valve body.

The valve is operated at a suitable frequency so as to apply a pulsed or intermittent suction to the gutter and thus reduce the amount of air drawn into the throat of the venturi pump to an acceptable level. As indicated above, the valve can be operated to cycle between its fully open and fully closed positions. However, when the valve is in the fully closed position, the venturi pump will tend to draw a vacuum in the duct between the pump and the valve. This will in turn affect the pressure in the main ink flow through the venturi pump and the ink pressure at the ink jet print head. In order to minimise these pressure reduction effects, the valve between the gutter and the venturi pump may be operated so that it does not close fully, for example so that it reduces the flow to between 10 and 25% of the full flow value. For convenience, the

term closed or shut will be used herein to denote the position of minimum flow permitted through the valve and is not limited to the case where the valve is fully closed. The frequency of operation of the valve may also reduce the effects of the pressure reduction on the main ink flow through the venturi pump effect and we prefer to operate the valve at a frequency of less than 10 cycles per second.

Preferably, the valve is operated so that the duct between the gutter and the valve is always at least partially filled with ink which has drained into the duct from the gutter. The residual fluid in the duct upstream of the valve member thus acts as an air lock between the ink flow system downstream of the valve and the gutter. If desired, the duct may be formed with a sump or other trap in it to assist the air lock action of the fluid in the duct. Since the amount of ink which is collected in the gutter per unit time as un-printed droplets will vary considerably according to the nature of the image being printed on the substrate, it may not prove possible to maintain this air lock at all operating conditions of the printer without causing overfilling of the duct between actuations of the valve in the duct. It is therefore preferred to operate the valve so that it will maintain at least a small residue of ink in the duct between actuations of the valve at the expected maximum rate of capture of un-printed droplets by the gutter or catcher.

The operation of the valve comprises periods when the valve is closed and fluid is collecting in the duct and gutter upstream of the valve, and periods when the valve

is open and fluid is drawn through the valve and potentially empties the duct and gutter to draw air into the throat of the venturi and hence into the main ink flow system of the printer. The optimum open and shut periods, or duty cycles, of the operation of the valve can readily be determined by simple and trial tests for a given type of operation of the print head. Typically, the valve closed periods will be from 1 to 20 times the duration of the valve open periods, that is that the valve is operated at an open duty cycle of from 5 to 50%.

The open periods of the valve operation will occur as often as is required to maintain the desired level of ink in the gutter. However, we have found that if the valve is held closed for prolonged periods or the valve is operated too frequently, this may affect the pressure in the main ink flow system at the print head and thus affect the ejection of droplets from the nozzle of the print head. We therefore prefer to operate the valve at high frequency, for example from 2 to 10 times per second, so as to reduce the formation of pressure variations at the print head.

In a particularly preferred embodiment, the valve is operated at from 2 to 5 Hz at an open duty cycle of 12 to 25%.

It is also preferred that the open duty cycle and the frequency of operation of the valve should be variable, for example by means of the software controlling the application of electrical power to operate the solenoid of the valve mechanism. Thus, the operation of the valve may

be varied to suit changes in ambient and other conditions, for example to reflect changes in ink composition or the effect of temperature on the viscosity of the ink flowing through the gutter and associated ducts. Such variation of the operation of the valve can be achieved using conventional software techniques.

We have found that the method and apparatus of the invention can achieve reductions of 67% or more in the amount of air drawn into the ink flow system of the printer and that it may b possible to reduce the amount of solvent vapour or droplets entrained in the air discharged from the reservoir of the ink flow system to levels at which the air stream can be discharged directly to the environment without further treatment. However, if desired the mixture of fluid ink, solvent and air from the gutter may be cooled or subjected to other forms of treatment before it is fed to the reservoir of the ink flow system of the printer and/or the air discharging from the reservoir may be cooled or otherwise treated to reduce the level of solvent droplets and/or vapour therein before discharge to the environment. Such cooling or other treatments may be of a conventional nature.

The above operation of the valve mechanism may be modified to enhance its operation. For example, in order to assist flow of the ink captured by the gutter to the valve, it may be desired to provide an enlarged portion to the duct between the valve and the gutter, for example a portion having a diameter from 1.5 to 5 times the diameter of the inlet port to the valve. Such enlarged diameter portion may also provide a quiescent zone which assists separation

of fine droplets or mist particles of ink or solvent from any air which is drawn into the duct when the valve is opened. Typically, such an enlarged portion of the duct is provided by the use of a larger than usual duct between the gutter and the inlet to the valve. Such a larger diameter portion of the duct may be cooled, for example by providing a Peltier effect device as a sleeve around the duct, to assist condensation and separation of any droplets from the air phase in the duct.

When the valve is closed, this will allow a reduced pressure to be drawn by the venturi pump on any ink which remains in that portion of the duct between the valve and the throat of the venturi into which the duct debouches. Such reduced pressure may cause localised evaporation of solvent and other volatile components from the ink in the duct. Such evaporation is undesirable, since it may lead to the formation of bubbles within the ink recycled to the reservoir of the ink flow system of the printer which could lead to malfunction of the print head. In order to reduce this, it may be desirable to provide means by which the valve does not wholly close, and such means may also reduce the pressure effects on the main flow of ink as described above. For example, the plug or flap of the valve may be rotated so that it does not wholly close off the fluid flow path through the valve, but maintains a small bleed flow path, typically from 5 to 15% of the fully open flow path, through which fluid can bleed to maintain the pressure in the portion of the duct downstream of the valve to above that at which excessive evaporation of the volatile components of the ink in that portion of the duct occurs.

DESCRIPTION OF THE DRAWINGS:

A preferred embodiment of the invention will now be described by way of illustration only with respect to Figure 1 of the accompanying drawing which is a diagrammatic block diagram of a portion of the ink flow system of an ink jet printer.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

A conventional continuous ink jet printer comprises a print head (not shown) which ejects a stream of droplets 1. Some of these are deflected so as to land upon a paper or other substrate and thus form a printed image. Others are not deflected and follow a straight line flight path into a gutter 2 so that they are not applied to the substrate. The droplets captured by the gutter 2 are returned to the reservoir 3 of the main ink flow system of printer, shown diagrammatically by line 4.

Typically, the ink is drawn from gutter 2 by connecting the gutter outlet to the throat 10 of a venturi pump 11 which is powered by the flow of ink through it driven by the main ink circulation pump 12 pumping ink through the nozzles of the print head (not shown). A linearly acting solenoid valve 13 is located in the duct 14 connecting the throat of the venturi pump 11 to the outlet to gutter 2.

Valve 13 is operated by a control circuit 20 which regulates the extent of closure, the open/closed duty of the valve and the frequency of operation of the valve.

Circuit 20 and the software controlling its operation are of conventional design and manufacture. Typically, the valve is to operate at a 10 to 20% open duty cycle and at a frequency of from 1 to 5 cycles per second. The valve 13 is operated during the printing operation.

It is preferred to modify the operation of the valve in response to changes in the ink composition, the ambient temperature and pressure and other factors which are known in the ink jet printing field to affect the flow of ink and the operation of an ink jet printer. It will therefore usually be preferred to provide some suitable sensor 30 to detect changes in ambient conditions and also to provide a facility for inputting changes to the software controlling the operation of valve 12.

CLAIMS:

1. A method for operating a continuous ink jet printer so as to reduce the loss of volatile solvent or carrier from ink recycled from a gutter to a reservoir, the printer having an ink flow system in which ink flows from a reservoir to a print head from which it is ejected to form a series of discrete droplets directed at a substrate upon which an image is to be formed by applying droplets to the surface of the substrate and in which droplets which are not to be applied to the substrate are collected in the gutter and are recycled to the reservoir of the ink flow system for re-use, the method comprising removing ink from the gutter by suction which is varied, pulsed or interrupted.

2. A continuous ink jet printer having an ink flow system in which ink is adapted to flow from a reservoir to a print head from which it is ejected to form a series of discrete droplets directed at a substrate upon which an image is to be formed by applying droplets to the surface of the substrate and in which droplets which are not to be applied to the substrate are to be collected in a gutter and recycled by means of suction via a duct to the ink flow system for re-use, characterised in that means are provided for varying, interrupting or pulsing the application of suction to the gutter.

3. A method or apparatus as claimed in either of claims 1 or 2, characterised in that the suction is provided by a suction pump which is to operate continuously during operation of the ink jet printer and a valve means is

provided in the duct providing the fluid flow connection for the un-printed droplets between the gutter and the suction pump for varying, interrupting or pulsing the flow of fluid between the gutter and the suction pump.

4. A method or apparatus as claimed in any one of the preceding claims, wherein the suction is applied by connecting the gutter to the throat of a venturi pump through which part of the main ink flow of the ink jet printer flows.

5. A method as claimed in claims 1, characterised in that the suction to the gutter is interrupted by operating a valve in the line connecting the gutter to the source of vacuum and the valve is cycled between an at least partially open position and an at least partially closed position at a frequency of less than 10 cycles per second.

6. A method as claimed in claim 5, characterised in that the valve is operated at an open duty cycle of between 5 and 50%.

7. Apparatus as claimed in any one of claims 2 to 4, characterised in that sensor means are provided to vary the operation of the means controlling the variation of the suction in response to variations in ambient conditions.

8. A method or apparatus as claimed in Claim 3, wherein means are provided for controlling the open/shut duty cycle of the valve and/or the frequency of implementation of the cycle of the valve during the printing operation.

9. A method or apparatus according to either of claims 1 or 2, substantially as hereinbefore described with respect to the accompanying drawing.

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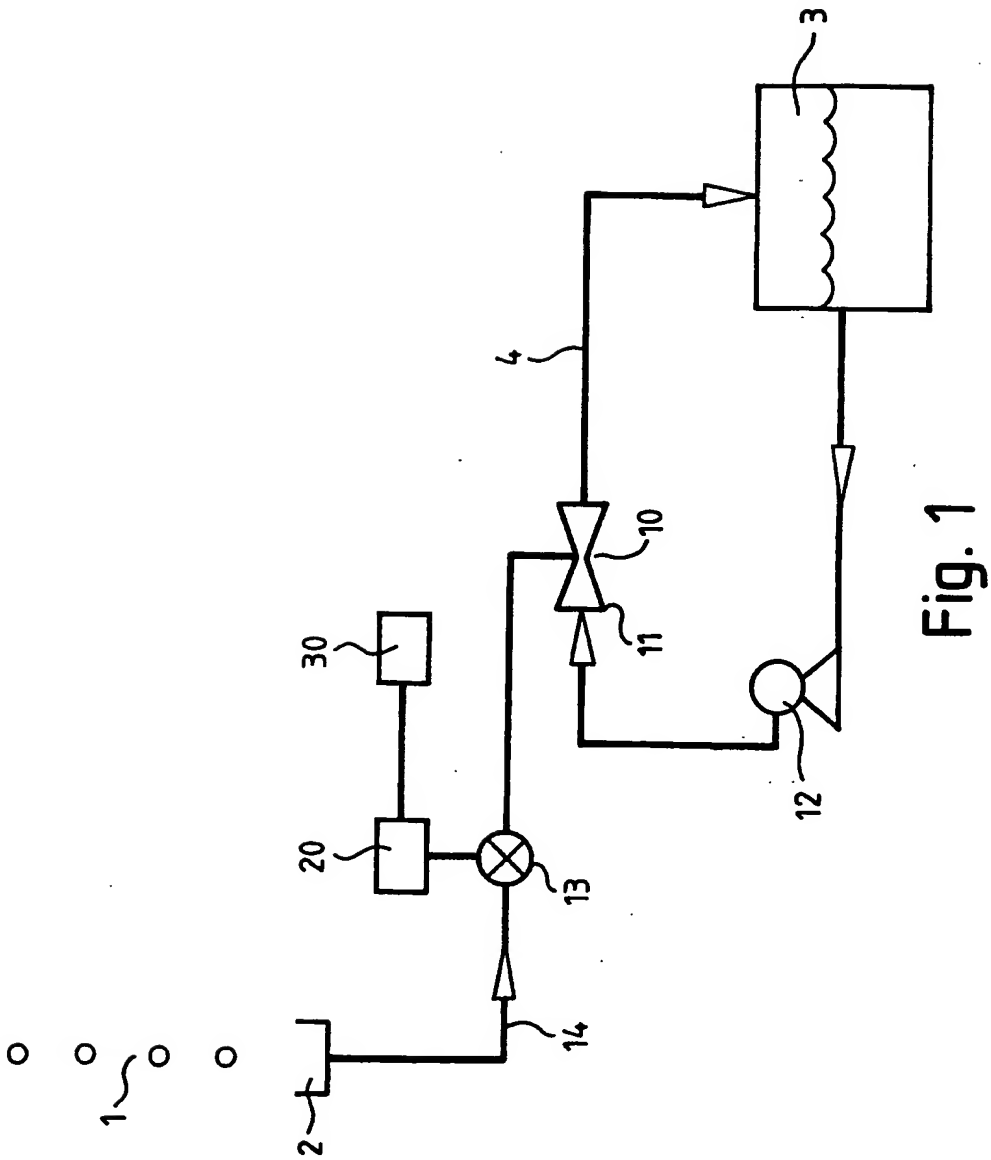

Fig. 1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/01482

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B41J2/175 B41J2/18 B41J2/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B41J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 17478 A (DOMINO PRINTING SCIENCES PLC ;MCKEE JAMES P (US)) 30 April 1998 (1998-04-30)	1-3,8
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A	the whole document	7
Y	US 4 614 948 A (KATERBERG JAMES A ET AL) 30 September 1986 (1986-09-30) the whole document	4

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Information on patent family members

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